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Hf Isotope Evidence for Mantle Domain Boundaries in the Western Pacific

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Introduction

It is well known that Pacific and Indian MORB have distinctive isotopic compositions, and that a boundary between Pacific and Indian upper mantle isotopic domains occurs along the Australian-Antarctic Discordance. However, the nature, location and evolution of this mantle domain boundary on a global scale are poorly constrained. Pb isotopes have been the most distinctive and widely-used discriminant of Indian MORB-source mantle (IMM) and Pacific MORB-source mantle (PMM). Using this indicator, Hickey-Vargas et al. (1995) suggested that most of the back-arc basins in the western Pacific formed by sea floor spreading during the Cenozoic have Indian Ocean Pb isotope signatures. However, it is now widely recognized that the Pb isotope composition of arc volcanics is controlled by the contribution from the subducted slab and/or sediment carapace, making this an frequently unreliable tracer of mantle wedge provenance.

In a recent study of the Izu-Bonin-Marianas arc and back-arc system, Pearce et al. (1999) showed that Hf-Nd isotopes can be used to discriminate between IMM and PMM. In Hf-Nd isotope space, lavas from IMM and PMM sources form separate, sub-parallel trends with the Indian domain displaced to lower Nd and higher Hf isotope ratios. Because Hf and Nd isotope ratios are relatively immune to the effects of alteration and much more conservative than Pb during arc magma genesis, they reflect the composition of the mantle wedge more directly than Pb isotopes.

Our aim here is to apply the Hf-Nd isotope IMM-PMM discriminant to the Eocene-Recent volcanic rocks of the Tonga-Fiji-Vanuatu region, in order to track IMM and PMM domains in space and time and hence to understand better the complex interaction between mantle flow and subduction processes in the Western Pacific region.

Results

Our new data are shown in Figure 1. In general, mantle sources of Indian provenance appear to predominate, particularly for the Tonga/Lau and Vanuatu arc-basin systems. Both systems encompass a number of markedly different trends, all converging on a central portion of the diagram near the IMM-PMM boundary. However, a full interpretation of the data requires a correction (not shown here through lack of space) for subduction-derived Nd, and a detailed re-evaluation of the precise position of the discriminant boundary.

For subduction-corrected data from the Tonga/Lau system, the older volcanic rocks from 'Eua and the Lau Ridge (~5-40 Ma) have transitional IMM-PMM provenance. For the recent arc, the southern arc volcano of Ata (~10 ka) appears to have a PMM signature, but the Eastern and Central Lau Basin and the central Tofua arc have IMM signatures and the Northern Lau Basin and northern Tofua arc have strong IMM signatures. Thus there is a distinct change in mantle provenance along the active arc-basin system. Data for the active Vanuatu system overlap that of Tonga/Lau, but trend to lower Hf and Nd isotope values. Like Tonga/Lau, lavas from the southern part of the arc plot in the transitional region between IMM and PMM, but the more northerly volcanoes and two samples from the North Fiji Basin show a clearer IMM signature. Between the Tonga/Lau and Vanuatu systems, the Fijian islands (7-40 Ma) form a near-vertical trend that reflects in part a temporal change from PMM to IMM.

Conclusions

The new Hf-Nd isotope data for the Tonga-Fiji-Vanuatu region raise questions as to the precise origin of the IMM-like signature observed in many of the lavas. Ongoing work is targeted at evaluating three alternatives models: (1) rapid influx of true Indian MORB-source mantle from the northwest; (2) contamination of Pacific MORB mantle by one or more SW Pacific plumes; and (3) rafting of continental lithospheric mantle away from Australia during opening of the Tasman Sea. The compositions of younger volcanics are clearly influenced by the influx of Samoan-modified MORB into the North Fiji and Northern Lau Basins but the temporal variations require other explanations. A further point of note is that Hf-Nd isotope systematics do not obviously support a role for subducted Louisville sediments. In summary, the ability of Hf-Nd isotope co-variations to "see through" the subduction signature makes it an important tool for evaluating models of mantle flow for the region.

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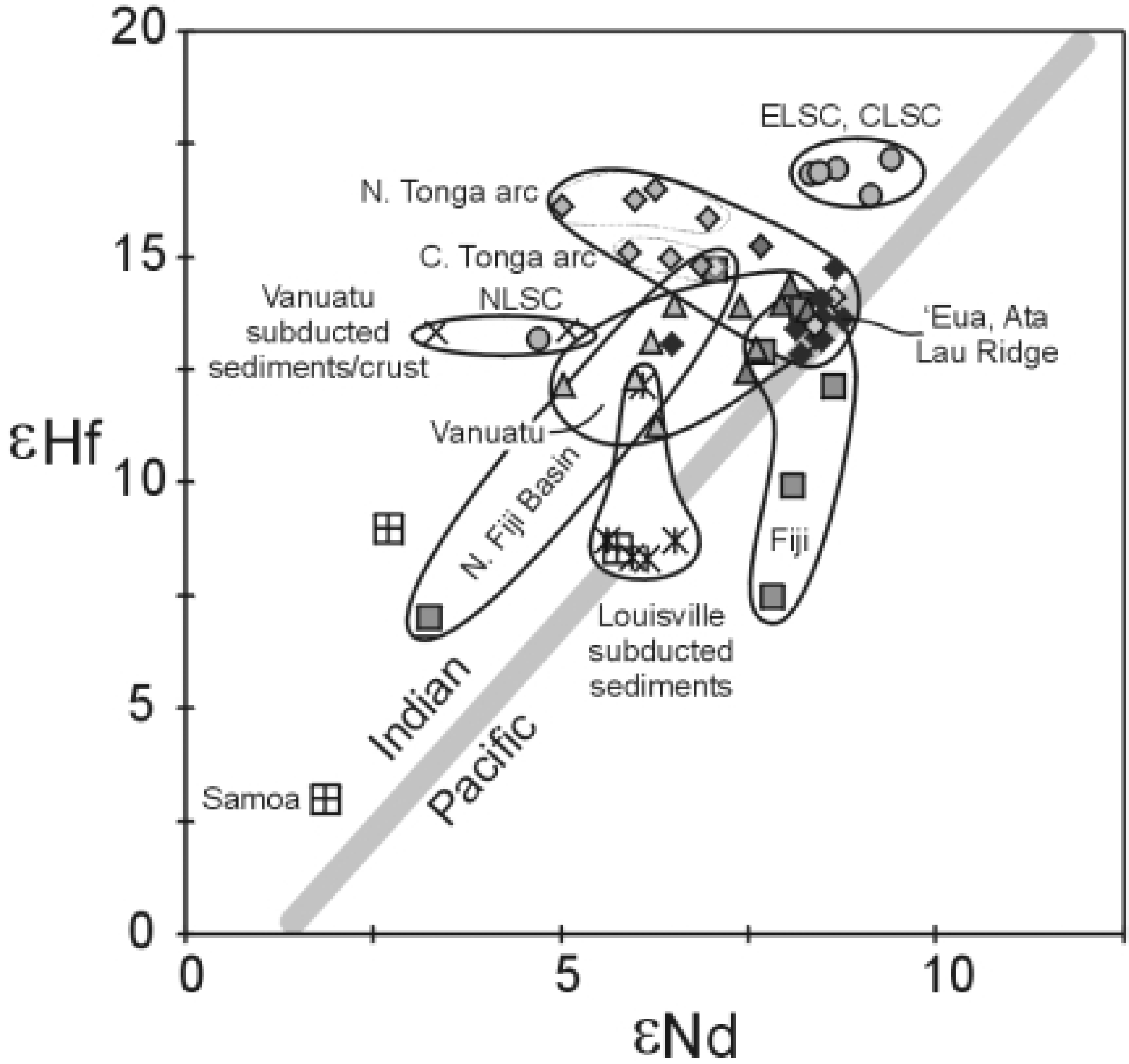

Figure 1. Hf vs. Nd isotope plot for the Tonga-Fiji-Vanuatu arc and back-arc systems. It should be noted that the data have not been corrected for any subduction addition of Nd and/or Hf, which may shift the data points depending on the amount and isotopic composition of the element added to the mantle wedge.

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